easy to cause a tactile sensation for compared to other points, it is not possible to perform appropriate volume adjustment based on the stimulation of these points. This measure is necessary because of fluctuations in the extent of a tactile sensation due to location of a finger in the event of electrical stimulation. With regards to reading speed adjustment, the speed is changed by the extent of three stages as a result of every pushing of one push button switch.

[B-4] Measurement of Stimulation Current/Voltage and Utilization of this Information

Background and Object

[0071] Approaches to estimating electrical impedance of skin based on skin structure by measuring stimulation current and voltage are well established. With regards to the finger tip, there is that carried out by the inventors of this application (Takahashi, Kajimoto, Kawakami, Kan, "electrical stimulation using two electrodes of an anode and cathode with the object of presenting sensations to skin", The Society of Instrument and Control Engineers System Integration Department Lecture (Tokyo, December 2003), 2B2-3, 2003). The object is to obtain a relationship of correlation between skin impedance and stimulation current tactile sense threshold value and connect this to stability of tactile sensations. However, a number of findings have been made with regards to the correlation relationship, but there has been no success with regards to achieving stable sensations. The following describes a novel way of utilizing impedance information.

[Resolving Means 1 (Power Saving)]

[0072] Saving consumed power is an important problem with regards to the mobile type electro-tactile display. The electric stimulation circuit is basically controlled by current. Even if the power supply voltage is fixed, the voltage actually applied to the skin depends on the resistance of the skin. Energy that is determined by the product of the resistance and current flowing as a result of a difference in voltage between the power supply voltage and the voltage on the skin is consumed as heat in the electrical circuit. It is possible to keep the power consumed low by dropping the power supply voltage to close to the voltage applied to the skin.

[0073] In a specific method, for example, a technique may be considered where the power supply voltage and voltage applied to the skin are compared and the power supply voltage is adjusted so that the difference becomes small. Alternatively, the command current and actual current flowing are compared, with the power supply voltage being raised if the actual current flowing is smaller than the command current, and being made to fall when this is not the case.

[Resolving Means 2 (Safety Countermeasures)]

[0074] It is possible to determine whether or not each electrode is reliably making contact with the skin by measuring impedance of every electrode. Here, a method is adopted where only points where contact is actually being made (=impedance is lower than set threshold value) are stimulated, with there being no stimulation when this is not the case. In particular, in the case of a multipoint electrical stimulation using a matrix-shaped electrode, it is likely that contact of end portions of contact area is insufficient. At this time, the electrical stimulation is carried out by electrical control. The voltage therefore dramatically rises at locations where the contact is insufficient (i.e. locations where the impedance is high). Substantial joule heat is therefore generated as a result and this leads to the generation of pain. A precise contact determination by measuring impedance of each electrode and switching of stimulation according to this determination is required at an electrode matrix in order to suppress the generation of the pain.

[Resolving Means 3 (Use as a Force Sensor)]

[0075] It is also possible to calculate the contact surface area of a finger by measuring impedance for each electrode. Basically, the contact surface area becomes broader as the pressing force of a finger becomes stronger. Contact surface area information can therefore be converted to force information. It can be used as a substitute for the force sensor described in [B-3]

[B-5] High-Speed Localized Switching

[0076] With regards to the problem that sufficient stimulation is not possible when electrode interval is narrow in electrode stimulation employing arrayed electrodes, the amount of stimulation is increased by a localized switching algorithm and spatial resolution of the stimulation is held as is. The electrode at a position for stimulation and electrodes in the vicinity of the electrode are used as current sources, and the neighboring electrodes other than the electrode at a position for stimulation are alternately switched at high-speed so as to alternate between a current source and ground. A detailed configuration is disclosed in [A].

[B-6] Reduction of Stimulation Period Duration

Background and Object

[0077] The inventors of this application propose accentuating temporal and spatial changes in electrical stimulation and then providing stimulation. This is a method of simulating a physical phenomena occurring in mechanical stimulation in electrical stimulation. Specifically, first, stimulation is further reinforced while stimulation is strengthened at certain stimulation points with respect to time. It is known that receptors responding only when deformation fluctuating with time occurs in the skin of a person (Meisner's corpuscles) exist. Time fluctuation is naturally reinforced by these receptors with mechanical stimulation. The same reinforcement is also implemented with electrical stimulation (Kajimoto, Inami, Kawakami and Tachi, The SmartSkin: Augmentation of Skin Sensation with Electro-Tactile Display; "Research into augmented reality (third report), Proceedings of the Virtual Reality Society of Japan Seventh Annual Conference (Tokyo, September 2002), pp. 149-152, 2002).

[0078] Next, spatially, in the event of mechanical contact, as a result of a spatial band-pass filter characteristic (intermediate frequency pass characteristic) caused by the finger being an elastic body, stress is focused on edge portions of the contact surface, so that edge accentuation takes place naturally (FIG. **13**). It has also been proposed to increase stimulation pulse frequency at edges in order to implement the same results for electro-stimulation ("Kajimoto, Kawakami, Maeda, Kan" Active Touch in Electrocutaneous Display", Proceedings of the Virtual Reality Society of Japan Sixth Annual Conference (Nagasaki, September 2001) pp. 489-490, 2001).

[0079] As a result of the above, with regards to a stimulation point for one point, three types of stimulation of "normal